Stated Choice for Transportation Demand Management Models

Using a Disaggregate Truth Set To Study Predictive Validity

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Discrete choice models have expanded the ability of transportation planners to forecast future trends. Where new services or policies are proposed, the stated-choice approach can provide an objective basis for forecasts. Stated-choice models are subject to a range of experimental error not found in revealed-preference designs. Primary among the concerns facing researchers is the ability of respondents to understand and operate on hypothetical choice scenarios in a manner that will reproduce choices made under actual situations. These concerns are specified in the scaling factor. Estimation of the scaling factor has proceeded through various ways to link actual decisions to comparable decisions made under hypothetical conditions. However, where the alternative is new, real decision data are not available. The level of error incorporated in a study where no real-world information on the scaling factor is available is examined. The test of predictive validity focuses attention on the switching behavior of commuters at a single employment site. The results indicate that switching behavior between single-occupant vehicle and high-occupancy vehicle modes is forecast within 1 percent by stated-choice techniques and within 10 percent by backcasting techniques with revealed-preference data.

Stated-preference (SP) models continue to attract attention and to be used for forecasting purposes (*1*). However, remarkably few studies focus on the predictive validity of the method. Absent evidence demonstrating the level of performance to be expected for SP-type exercises, questions of validity remain. This paper contributes to the growing evidence involving the predictive validity for stated-choice (SC) methods. The results are limited to the choice of commuting mode. The modes are single-occupant vehicle (SOV) and public transit linked with free shuttle bus service supplied by an employer.

Two types of predictive validity test are applied to the data: forecast and backcast. Predictive validity, when applied to SC, focuses on the counterfactual conditional: If X had happened, then Y would have followed. The antecedent of the if-then proposition asserts a value for an X variable, and the consequent indicates the resulting value of Y. A forecast provides a future value for the consequent, and a backcast abstracts from time and produces a value for a consequent in past time given a value for the antecedent X in current time. Because policy analysis is usually future oriented, the counterfactual conditional logic is commonly embedded in a forecast; the backcast is used as an analytical tool to test a model.

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LITERATURE REVIEW

SC models have evolved through several stages. Early work was concerned with theoretical issues (*2,3*) or methodological development (*4,5*). As the method gained in methodological soundness, researchers have turned to the problem of external validity (*6*). Studies of external validity evolved into matched or linked revealed-preference (RP) and SC models (*7*). Early work in the linkage of the two models revealed a conceptual dilemma that has dogged efforts ever since. Ben-Akiva and Morikawa (*8*) recognize that RP, when estimated by conditional logit techniques, model stationary choice behavior. In essence, unless the sample was derived from a population of mode switchers over a known time interval, revealed choice behavior is confounded with the transaction costs of switching. SC, on the other hand, focuses directly on switching choice behavior. Here also, perceived transaction costs of switching can be confounded with other unspecified mode-specific properties that are embedded in the alternative specific constant. Simultaneously, it was recognized that both RP and SC had their own beneficial features as well as shortcomings. Building on the unique properties of each method, Morikawa (*9*) and Swait et al. (*10*) found conditions where the joint estimation procedure was not appropriate; in turn, they suggested and demonstrated the usefulness in sequential estimation of RP and SC. Paralleling the comparison of RP with SC models, a concern for predictive validity is also emerging. Bradley and Kroes (*7*) indicate the need to perform before-and-after studies to fully explore the external validity of hypothetical choice models. This is the task undertaken in this study.

RESEARCH DESIGN

The opportunity to construct a before-and-after predictive validity test and comparison of RP and SC arose through the fortuitous acquisition of two research contracts from different sources. There was no intent with the first contract to perform a follow-up study and no consideration was given to creating a panel study. However, given the flexibility gained in the second contract, a common research design was followed for both studies. The concepts used to guide data generation and analysis were random utility theory (*11*) and the theory of reasoned action (*12*). The theoretical models provided a framework within which to identify the observable dependent and independent variables.

Data generation was guided by previous work reported by the authors (*13*). First, focus groups were set up with employees from the target population. After the focus group sessions, revisions were made to the draft survey instruments and a second wave of focus groups was set up. The second wave also was used as a pilot test of the survey instrument. Again, revisions were made in the instruments and, upon approval from the site manager, a random employee-selection process was followed. The instrument package was prepared on laser-printer single-sided paper and given to the site manager for distribution and recovery.

The analytical component of both studies used the conditional logit program found in ALOGIT 3.2f (*14*). The conditional logit model is

$$P_i = \frac{e^{\mu V_i}}{e^{\mu V_i} + \sum_j e^{\mu V_j}} \tag{1}$$

where j is all other alternatives.

Equation 1, with the index for the individual decision maker suppressed, shows P_i to be the probability that individual n chooses alternative i from a choice set that includes all other alternatives j, which are also members of $\{I\}$; $\{V_i\}$ are systematic utility functions for each of the choice alternatives in choice set $\{I\}$. The relationship among attributes in $\{V_i\}$ is usually assumed to be linear and is presented in Equation 2.

$$V_{ni} = f(\alpha_{ik} X_{nik}) \tag{2}$$

Where α_{ik} is the set of parameters for the function containing the k attributes X_{nik} of alternative i, the socioeconomic characteristics, and the attitudes and beliefs of decision maker n toward the act of commuting by mode.

The scale parameter μ in Equation 1 is inversely related to the square root of the variance (σ^2) of the random disturbance term (*15*). Maximum-likelihood estimation (MLE) procedures are used to estimate the parameters for both RP and SC types of data bases. In the case of logit models, the estimates from MLE are scaled estimates and the variance of the disturbance term must be estimated to derive consistent choice probabilities. RP and SC exercises usually are believed to have different scaling factors. Given that the two models were generated independently and contain different variables, there is no direct way to scale one model on the other as is done in joint and sequential model estimation practices. As a consequence, the estimators reported for both models are scaled estimators whose values reflect sampling error as well as differential scaling. Comparison of the two models for evaluation purposes relies on their individual tests of predictive validity.

The Site

The site for the predictive validity test is the administrative headquarters for approximately 566 employees of the Port Authority of New York and New Jersey (PATC). The site is located in Jersey City, New Jersey, approximately one-quarter of a mile (0.4 km) from the Hudson River, three-quarters of a mile (1.2 km) from the Hoboken Ferry Terminal, 2 mi (3.3 km) from the Journal Square Station in Jersey City, New Jersey, and 8 mi (12.9 km) from Pennsylvania Station in Newark, New Jersey. One or more of the region's commuter rail lines and many bus routes serve each of these transportation centers. However, no transit routes directly serve the site. The site consists of a two-story building located on the highway leading to the Holland Tunnel and includes three parking lots. Parking is currently free of charge to PATC employees. The parking lots can handle 396 cars. As of November 1992, 64 percent of employees drove alone to work, 12 percent carpooled, and 24 percent used public transit. Most employees have at one time or another been forced to park off-site. Most off-site parking is on local streets, where there is some concern about vandalism. Usually, public transit users also use the PATC shuttle bus service to travel from the Hoboken Ferry Terminal to the PATC site.

PATC shuttle bus service is based on the use of 14 passenger center-isle vehicles. Shuttle service to the Hoboken Terminal starts at 6:00 a.m. and has 15-minute headways during peak hours. All passengers must be seated; consequently, any overflow must be accommodated on the next shuttle or employees must walk the 15-minute trip to or from the PATC site. In addition to the Hoboken Terminal service, a second shuttle links PATC with the Port Authority's World Trade Center in Manhattan. This service begins at 9:00 a.m. and has a limited effect on the commuting decisions of PATC employees.

Two policy changes have altered the relative satisfaction commuters obtain from their trip to work. In January 1993, the Port Authority Board of Directors authorized payment of an employee transportation benefit of $60 per month to transit users. All transit use by employees is linked to the Hoboken Transit Center by the PATC shuttle bus. No effort was made to promote the transit check program until summer 1993. Consequently, the most immediate beneficiaries of the program were existing transit users who discovered and applied for the benefit during spring 1993. During summer 1994, promotion efforts began and enrollment in the transit check program increased. No other new trip-reduction programs were prepared for technical center employees as of winter 1994.

During early spring 1995, a new shuttle bus route was initiated by the Port Authority. The route links the technical center to the Port Authority Trans-Hudson subway line in Jersey City. The link runs on 20-minute headways, whereas the Hoboken route has 15-minute headways; all other characteristics are essentially the same.

The Surveys

Between November 1993 and May 1993, a series of surveys were administered to PATC employees. The surveys contained descriptive, attitudinal, and SC types of data. Again, during summer 1995, a second employee transportation survey was administered to employees of the technical center. The survey was limited to descriptive, attitudinal, and RP data. No effort was made to match respondents in 1993 with those in 1995. The employee selection and survey distribution procedures were identical to those in the 1993 stated-preference survey. The 1995 survey generated 210 completed instruments from an estimated 566 employees.

COMPARISON OF SURVEYS

The 1993 survey generated 466 usable responses from an estimated permanent employment level of 587. The 1995 survey generated 210 usable surveys from an estimated total employment of 566. Table 1 displays a set of common statistics derived from the two surveys. Five characteristics can be used for comparison. The representative values for gender and median commute time are essentially identical across the two surveys. Perceived cost statistics have changed during the 2-year period. In the 1993 survey, respondents

TABLE 1 Comparison of Statistics Derived from 1993 and 1995 PATC Employee Transportation Surveys

Characteristic	1993 Survey	1995 Survey
Gender		
% male	78	78
Median one way commute travel time (minutes)		
SOV	45	45
Public Transit	80	77
Cost of round trip commute		
SOV	$3.27*	$4.00
Public Transit	$9.74**	$7.80
SOV Users attitude toward the use of Public Transit		
Extremely unpleasant	30%	27 %
Quite unpleasant	17 %	22 %
Slightly unpleasant	14 %	4 %
neutral	21 %	40 %
Slightly pleasant	7 %	2 %
Quite pleasant	7 %	1 %
Extremely pleasant	4 %	3 %
Mode Split		
% using SOV	61	53
% using Public Transit	23	32
Number of cases*	466	210
Population size:	587	567

* Average value to question: "What are your typical daily commuting costs (tolls, gas, parking) to the PATC?"
**Average value to question: "If or when you use public transit, what do you estimate your total fare (one way) for public transit to be for the commute to the PATC?" Average is doubled to make it comparable to the drive alone daily commuting costs.

perceived the round trip by SOV to cost $2.20 and public transit to be $9.00. The 1995 survey found that the perceived cost of median round trip by SOV was $4.00, whereas the public transit median round-trip fare was perceived to be $7.80. The ratio of the 1995 to 1993 perceived costs is used as a price index with the 1993 model in its forecasting mode; similarly, the ratio of 1993 to 1995 perceived costs is used as the comparable price index with the 1995 model to backcast to 1993 mode-choice probabilities.

Attitudes of SOV drivers toward public transit also can be compared across the two surveys. Extreme attitudes of pleasantness and unpleasantness remain essentially the same. However, within the extremes, there is a strong shift over time toward the characterization of public transit as unpleasant. Finally, measures of the utilization of the SOV mode versus transit show the percentage of employees using SOV to be declining from 61 to 53 percent, whereas public transit has increased from 23 to 32 percent. Given the degree of success PATC authorities have had in encouraging employees to shift to public transit, those employees who continue to use the SOV mode are more likely to have a negative attitude toward transit.

The 1993 SC Model

The SC experiment was designed and administered during winter 1992 and spring 1993. The structural model for the conditional logit, as indicated in Equation 3, consists of utility functions for four alternatives: the drive-alone commute and three public-transit alternatives differentiated by the route taken by the PATC shuttle bus.

$$
\begin{aligned}
V_1 &= a_{11}X_1 + a_{12}X_2 + a_{13}X_3^* + a_{14}X_4^* \\
V_2 &= a_{20} + a_{.5}X_5 + a_{.6}X_6 + a_{.7}X_7 + a_{.8}X_8^* + a_{.9}X_9^* + a_{.10}X_{10}^* \\
V_3 &= a_{30} + a_{.5}X_5 + a_{.6}X_6 + a_{.7}X_7 + a_{.8}X_8^* + a_{.9}X_9^* + a_{.10}X_{10}^* \\
V_4 &= a_{40} + a_{.5}X_5 + a_{.6}X_6 + a_{.7}X_7 + a_{.8}X_8^* + a_{.9}X_9^* + a_{.10}X_{10}^* \, *
\end{aligned}
\qquad (3)
$$

The arguments to the SOV utility function are listed below, where the asterisk represents a design variable:

1. Employee has an assigned parking spot (X_1);
2. Perceived daily drive-alone commute cost (X_2);
3. New parking charges (X_3)*; and
4. Availability of on-site parking spaces (X_4)*.

The arguments to the public transit-shuttle bus equations are as follows:

1. Perceived current cost to use public transit (X_5);
2. Number of transfers currently used on commute by public transit (X_6);
3. Ingress time (X_7);
4. Starting time for shuttle bus operation (X_8)*;
5. Shuttle bus vehicle (X_9)*; and
6. Headway for shuttle bus operations (X_{10})*.

Alternative specific constants incorporated into the public transit-shuttle bus equations are as follows:

1. Hoboken shuttle bus (a_{20});
2. Hypothetical Newark Penn Station shuttle bus (a_{30}); and
3. Hypothetical Jersey City Port Authority Trans-Hudson stations shuttle bus, placed in operation January 1995 (a_{40}).

The drive-alone commute option is specified with two covariates and two design attributes. The covariates are driving cost and an assigned parking space. Values for all covariates are derived from the descriptive and attitudinal components of the transportation survey. The covariates are hypothesized to operate in opposite directions. The money cost of the drive-alone commute ceteris paribus is inversely related to the utility gained from commuting by the drive-alone mode. On the other hand, the opportunity to drive alone is enhanced by the perception that the respondent has a reserved parking space. A yes response to reserved parking should be positively related to the utility of driving alone to work.

Two design variables have been constructed for the drive-alone alternative: parking charges and availability of unassigned parking spaces. The parking charge variable adds to the existing cost of driving alone by assigning a daily rate for parking on the employment site. As in the case of the factual cost variable, it is hypothesized that imposition of parking charges will have a negative effect on the utility of driving alone and that the coefficient will be larger than that for the current cost of driving to work. Given budget constraints, it is hypothesized that the marginal disutility of the additional parking charge will be larger than the marginal disutility for the current daily cost of driving alone to work given free parking.

The utility function representing the public transit commute option is specified through four covariates, three design variables, and three alternative specific constants. Incorporated into the alternative specific constants are two characteristics of the public transit alternatives that were held constant for the study: a transit subsidy program valued at $3.00 per day and the availability of an emergency-ride-home program. The covariates describe the money cost, the inconvenience cost in terms of number of transfers, and the time cost in terms of time consumed to get from home to the public transit stop. All three covariates represent elements of cost in using public transit; therefore, it is hypothesized that each variable will have a negative effect on the utility of public transit for the commute to work. The fourth covariate specifies the means of getting to the public transit stop from home. The question asks individuals if they were dropped off near the transit stop instead of using a park and ride or walking to the transit stop. Relative to the other ways of getting to public transit, those who are dropped off will probably find their trip to work by public transit easier and will generate positive utility on this attribute.

The design variables for public transit reflect the policy options of interest to the PATC at the time of the study. The design variables describe level-of-service attributes for the shuttle bus leg of the commute by public transit. The attributes are headway, size of bus, and start time for shuttle operations. Increased headways detract from the convenience of transit and are therefore hypothesized to have a negative effect on the utility of taking public transit. Similarly, a shuttle bus operation that starts after the main work shift begins has reduced value for commuters and is therefore hypothesized to have a negative effect on utility. Last, given that the currently used vehicles do not permit standing, commuters occasionally must wait at the transit station for a shuttle bus with available seating. A vehicle with standing room will reduce this inconvenience, thereby producing positive utility for transit users.

The 1995 RP Model

The 1995 RP model is estimated for commuters who used either the SOV or transit and PATC shuttle modes and who were employed at PATC during the 1993 survey. The theory used to specify the RP model is essentially the same as that described for the SC model. The attributes used in the 1993 model as well as others were tested for inclusion in the 1995 equations. These variables include

1. Arguments to SOV utility function:
   - Employee has an assigned parking space,
   - Perceived SOV daily operating costs,
   - Availability of on-site parking spaces,
   - Driver performs other activities while commuting, and
   - Attitude toward driving alone for the commute.
2. Arguments to public transit PATC shuttle bus utility function:
   - Transit fare,
   - Employee is enrolled in PATC transit check program,
   - Monthly value of transit check,
   - Time spent getting to transit stop from home,
   - Perceived PATC shuttle bus headways,
   - Number of times per month employees were left at bus stop because of filled shuttle bus,
   - Employee is dropped off at transit stop by someone else, and
   - Attitude toward taking transit PATC shuttle bus for commute.

The justification for entering variables into the RP model is comparable to that for the SC model. Two additional variables are included in the RP model that were not available for the SC model. These variables scale the attitude of commuters toward either the SOV or the public transit PATC shuttle bus commute. Both variables are used to address the strength of the attitudes built up during past experience for one or the other commuting alternative. Morikawa (*9*) uses attitude to reduce spurious state dependence obtained from omitted variables. In the theory of reasoned action, attitude measured by the level of satisfaction acquired from using a commuting mode is the immediate precursor to the intention to use the commuting mode. The attitudinal variables are seven level numerical rating scales ranging from extremely unpleasant to neutral to extremely pleasant.

ESTIMATION RESULTS

SC Model

Table 2 displays the estimation equation for the SC model. The utility equation for the SOV alternative consists of four variables: cost, parking charge, parking availability, and assigned parking spaces. The coefficient for the squared value of the employee's perceived current daily cost for the drive-alone commute has a strong negative effect on the utility obtained for the SOV mode; however, the coefficient for the hypothetical new parking charge term, also using the square transformation, has a larger negative influence on the utility of driving alone than current costs. This suggests that commuters have an increasing marginal disutility to the costs of automobile usage. The availability of parking spaces when the employee arrives at work has a positive effect on utility as does the existence of an assigned parking space at the PATC parking lot. The former is an SC design variable, and the latter represents the current state of affairs. The former has variability within each commuter, and the latter has variability across individuals. There is no statistical difference between the two parking space coefficients even though there is greater uncertainty associated with unassigned parking spaces than with assigned spaces. Last, the 1993 SC model did not elicit attitudes toward commuting alternatives.

The three shuttle bus alternatives have seven generic variables and three alternative specific constants. Four of the generic variables are factual in that they represent the perceived value of the variable under current conditions. The remaining three generic variables are design variables selected through policy consideration by the Port Authority of New York and New Jersey. The estimated marginal utilities of the covariates are examined first. The covariates assess the effect of accessibility, money and time cost, and inconvenience of transit use on the utility of shuttle bus ridership. First, employees who use a park-and-ride lot when taking public transit in contrast to being dropped off at the station or being required to walk to the station, show a marked propensity to increase their interest in use of the shuttle bus. The perceived money and ingress time costs produce negative coefficients for shuttle bus ridership. Similarly, employees who are forced to use transfers have strongly increasing disutility for the shuttle bus option.

TABLE 2 Discrete Choice Estimation Equations for Commuting Choice Decisions Between SOV and Public Transit Shuttle Bus Modes Made by PATC Employees

Attribute	SC Logit Coefficients	RP Logit Coefficients
Single Occupant Vehicle		
Daily Drive Alone Cost Squared	-0.024 (6.3)[1]	-0.016 (0.9)
*Parking Charges at PATC Squared	-0.054 (8.0)	na
*Parking spaces available	0.45 (3.2)	na
Assigned Parking Space	0.40 (3.1)	2.06 (2.4)
Attitude toward SOV	na	1.19 (2.3)
PATC Shuttle Bus Equations:		
Dropped off at transit stop	0.61 (2.0)	0.34 (0.1)
Transit fare	-0.039 (1.8)	-0.41 (1.8)
Time from home to transit stop	-0.0066 (1.6)	-0.048 (0.9)
Number of transfers	-0.432 (6.8)	0.12 (0.2)
Use Transit Check	constant	3.24 (2.1)
Monthly value of Transit Check	constant	0.069 (1.1)
Guaranteed Ride Home	constant	na
*Shuttle bus starts at 8:30 a.m.	-1.06 (6.9)	na
*New Shuttle bus always has room to stand	0.36 (2.5)	na
*Headway on new shuttle buses	-0.027 (3.4)	na
Attitude toward Public Transit	na	1.05 (2.5)
*Use PATC Hoboken Shuttle (currently in operation)	0.43 (1.5)	na
*Use PATC Newark Penn Station Shuttle (Proposed)	-0.42 (1.4)	na
*Use PATC Jersey City Shuttle (Proposed)	-0.91 (3.0)	na
Initial Likelihood	-1677	-95
Final Likelihood	-1048	-14
Rho bar squared	.37	.84
Number of decision makers	138	183
Number of decisions	1210	183

[1]Values in parentheses are t-scores. t-scores for the SC equation are nominal values due to multiple responses by each respondent. na = not applicable.

Among the 10 generic variables used to determine utility for the shuttle bus, three were held constant for the SC model, three more were constructed as design variables, and four represented the actual constraints and opportunities typically experienced by PATC's commuters in spring 1993. The design variables held constant are represented by the existence of a transit check program, a transit subsidy program with a dollar value of the subsidy set at $3.00 per day, and a guaranteed emergency ride home requiring a 10-minute wait for the vehicle. The role of these variables in the decision making process is incorporated in the alternative specific constants for the three shuttle bus routes.

The three design variables defining PATC shuttle bus operations are daily starting time for operations, roominess of the vehicle used as the shuttle bus, and headway. The start time variables indicate that shifting the starting time for off-site pickups away from either 5:30 a.m. or 6:00 a.m. to 8:30 a.m. sharply reduces the desirability of the shuttle bus operation. Preliminary analysis indicated that employees are indifferent to a 5:30 a.m. or a 6:00 a.m. starting time.

The standing room variable addresses the often-mentioned concern of employees that PATC buses from Hoboken were filled during the morning peak period, requiring commuters to wait for another bus. Assuming that new buses that permit standing were to be acquired, the new shuttle operations would increase the utility of such buses. Finally, as headways increase from 10 to 30 min, the utility of the shuttle buses declines.

The alternative specific constants indicate that the existing PATC route to Hoboken is the most popular, followed by the Newark Penn Station terminal, and lastly the Jersey City connection with the Port Authority Trans-Hudson stations.

RP Model

Results from the RP model are indicated parallel to the SC equation in Table 2. As in the SC model, variables were included in the final RP estimation for theoretical reasons as well as for comparison with the SC model. Given that the standard errors and derived *t*-scores are assumed to be asymptotically unbiased in the RP model, they can also be used to make judgments for variables to be included in the final model.

Three variables are included in the final SOV utility equation. Drive-alone cost squared is indicated for comparative purposes even though the *t*-score is relatively low. A second point of comparison is the assigned parking space variable. The RP model generates a value five times that of the SC coefficient. Last, the respondent's ranking of satisfaction derived from commuting in a SOV shows a strong positive marginal utility; however, without comparable data from the SC study, no comparison can be made.

Seven coefficients are reported for the public transit PATC shuttle bus equation. The four strongest variables are transit fare, transit check program, value, and attitude toward transit and shuttle bus use when commuting to PATC. All the variables possess the theoretically correct signs. Three other variables were retained in the model in spite of their relatively low *t*-scores. These nominal variables include the following: dropped off at transit stop by someone, time to get to the transit stop from home, and number of transfers. None of these variables is used in the following validation segment.

In contrast to the SC equation, the RP model is extremely limited in the role it can play in informing decision makers. SC is able to explore policies that are not in effect. That is, SC can examine parking management policies, whereas the RP model is limited to the preexisting policy of assigned parking spaces. In addition, where confidence levels are required, the RP model has much wider levels than the SC model.

VALIDITY TESTS

Discrete choice models are judged on their ability to forecast switching behavior given changed conditions (*8*). Two policy changes within PATC have presented a natural experiment for a test of the predictive validity of RP and SC models. The new policies marketed to employees after the 1993 SC data were collected consist of a $3.00 per day transit subsidy and a new shuttle bus route. Two forms of validity tests are applied to the models. The 1993 SC model is used in a forecasting mode to estimate the market share for SOV commutes in 1995. The 1995 RP model is used to backcast market share for SOVs in 1993. Both the RP and the SC models apply the probabilistic forecasting method (*6*).

Stated Choice

The data base used to estimate the SC model was also used for predictive purposes. The data base consists of employees working at PATC as of spring 1993 who indicated that their typical commuting mode was SOV. Four attributes used to specify the SC model changed during the 2-year period. PATC policy resulted in a change in the value of transit subsidy. Two variables usually would be used to model the subsidy program; however, at the request of the sponsors of the research, the SC model incorporated a $3.00 per day transit subsidy as an alternative specific constant in each choice task. The second class of changes in the independent variable set involves a change in the perceived cost of travel. A price index for the one-way costs of commuting by SOV and public transit was computed from information supplied from both the 1993 and the 1995 surveys and displayed in Table 1.

The data for each respondent in the 1993 survey were updated to 1995 conditions and entered into the SC logit equation presented in Table 2. The probability of using SOV for the typical commute was computed for each respondent in the data base. The individual specific probabilities were averaged to form a market share for the sample. Table 3 indicates that the predicted market share for SOV changes from 100 percent in 1993 to a predicted 83.2 percent in 1995. The actual 1995 value reported from the subset of 1995 respondents who were SOV commuters in 1993 is 82.2 percent. The forecast for switching behavior is an underestimate of 1.0 percent. Given that the two surveys were independently administered without names being recorded, there is no way to determine whether the individuals who were predicted to shift commuting mode on the basis of the 1993 SC model actually changed behavior by 1995.

In a previously completed study with the same 1993 SC model, a comparable predictive validity test was performed with an aggregate truth set; that is, ridership data for the shuttle bus operation were available for the complete PATC operation for 1995. Aggregate truth sets suffer from the inability to alter the social and demographic attributes of the target sample to reflect the attributes from the base-year model. In this case, employment turnover changes the makeup of the 1995 PATC labor force, making it younger and more female. The predictive validity test constructed from the aggregate truth set indicates that the SC model overestimates the prediction by 15 percent (*16*).

TABLE 3 Predictive Validity Tests for SP and RP Commuting Mode Choice Experiments Performed on Employees Who Worked at PATC in 1993

Discrete Choice Model	1993	1995
1993 Stated Choice Model		
Actual SOV Mode Share in SC data base*	100 %	
Forecast SOV Mode Share†		83.2 %
Actual SOV Mode Share‡		82.2 %
Error		1.0 %
1995 Revealed Preference Model		
Actual HOV Mode Share§ taken from 1995 RP data base		100.0 %
Backcast HOV mode share	76.2 %	
Actual HOV Mode Share‖	65.8 %	
Error	10.4 %	

*1993 SC study was performed only on PATC employees who stated they typically used SOV to commute to work.

†1995 forecast is based on Conditional Logit SC equation applied to 1993 SC data base where all design variables are fixed at their 1995 values and perceived costs of SOV and transit are adjusted to 1995 prices, as described in the text.

‡Actual 1995 SOV share is derived from the 1995 RP study. First, employees who stated they typically commuted by SOV in 1993 were used as the test sample. The fraction of the test sample who switched to public transit-PATC shuttle bus was used to represent the actual SOV mode share in 1995.

§1995 RP based Conditional Logit equation is used to backcast the 1993 mode choice for employees who commuted by public transit-PATC shuttle bus in 1995, who worked at PATC in 1993, and used either SOV or public transit-PATC shuttle bus in 1993.

‖Given those commuters who used HOV in 1995, 65.8 percent indicated in the survey that they used high occupancy vehicles in 1993 and 34.2 percent indicated that they took SOV in 1993. Therefore, 34.2 percent of the sample shifted modes between 1993 and 1995. The RP model underestimated mode shifting by 10.4 percent.

RP

The predictive validity test for the RP model uses the backcasting mode to predict the percentage of 1995 public transit PATC shuttle bus commuters who would shift to SOV in the absence of the transit check program and new shuttle bus route. The process begins by identifying and selecting for analysis PATC employees who were employed by PATC in 1993 and who typically commuted in 1995 by public transit PATC shuttle bus. The data set was further structured to ensure that the 1995 public transit PATC shuttle bus commuters were either SOV or public transit PATC shuttle bus users in 1993. The RP model presented in Table 2 was then used to compute a 1993 mode share probability for each employee in the set.

The 1995 data set was adjusted to reflect the backcasted conditions for the right-hand side variables. Four variables were adjusted to reflect the conditions thought to best represent commuting conditions in 1993. The transit check program was removed and its dollar value was set equal to zero for all commuters in the backcast data base. Last, the 1995 perceived costs of driving alone and traveling by public transit were adjusted to 1993 dollars with the price index described. The data base adjusted to 1993 conditions was then used to compute individual probabilities for SOV and public transit PATC Shuttle.

Table 3 displays the results of these operations. The actual mode share for the sample is 100 percent public transit PATC shuttle bus in 1995. Backcasting to 1993, the model predicts that 76.2 percent were also public transit PATC shuttle bus users in 1993. The backcast data base also presents the commuters' statement regarding their reported typical commuting mode in 1993. Fewer than 66 percent of the employees in the set reported that they actually used public transit PATC shuttle for their typical commute in 1993. Whereas 34.2 percent of the sample represents switchers from SOV in 1993 to high-occupancy vehicle in 1995, the RP model suggests that only 24.8 percent will be switchers. The RP model underestimates switching behavior by approximately 10 percent.

DISCUSSION AND CONCLUSION

Random utility models are recognized as presenting forecasters with significant difficulties. These difficulties are observed most readily when an estimated discrete choice model is used to forecast switching behavior. RP methods traditionally have been accorded presumptive validity over SC methods. However, conceptual work spearheaded by Ben-Akiva and Morikawa and by Swait et al. question this presumption. Each method has its own strengths and weaknesses. Even worse, the two methods as commonly executed may identify entirely different choice processes, one representing stationary commuting behavior and the other representing switching commuting behavior. Therefore, on occasion, each method will have to rely on its own battery of reliability and validity tests for support.

These findings focus on switching behavior in the context of the commuter's mode choice decision. A discrete choice survey was administered twice at the same employment site with a separation of 2 years. Both RP and SC research designs were used and the results of both are compared for predictive validity. Results indicate that the SC model predicts within 1 percent of the actual degree of switching behavior for movement away from the SOV commute; the RP model backcasts within 10 percent for switching behavior away from the use of public transit during the same 2-year period.

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